MODELLING AND OPTIMISATION OF ASSEMBLY LINE BALANCING PROBLEM WITH RESOURCE CONSTRAINT

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering (Mechanical).

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

APRIL 2019

ACKNOWLEDGEMENTS

I would like to express the deepest appreciation to my supervisor Dr. Mohd Fadzil Faisae for imparting his knowledge and expertise in this research. Without his guidance, encouragement and patience this research will not be complete.

I would also like to express my very profound gratitude to my parents and husband, for providing me with unfailing support and continuous encouragement through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Finally, to my darling Zareef for being such a good and understanding little boy throughout my years of study, and making it possible for me to complete what I started. To those who indirectly contributed in this research, your kindness means a lot to me. Thank you very much.

ABSTRACT

Assembly Line Balancing (ALB) is about distributing the assembly tasks into workstations with the almost equal workload. Previous research mostly assumed that all workstations are having similar capabilities including the machines, tools and worker skills. Recently, researchers started to consider the resource constraints in ALB such as machine and worker. Optimisation of ALB with resource constraints gives a huge benefit to the industry such as increase line efficiency, optimise the resources utilisation and can reduce production cost. This research presents Assembly Line Balancing with resource constraints (ALB-RC) for a simple model with the objectives to minimise the workstation, machine and worker. For the optimisation purpose, this research introduces Genetic Algorithm (GA) with two new crossovers. The crossovers are developed using a ranking approach and known as rank-based crossover type I and type II (RBC-I and RBC-II). The GA with new crossover is tested against popular combinatorial crossovers with a wide range of problem difficulties consisting of 17 benchmark problems. The performance of the proposed GA with new crossover in optimisation ALB-RC is finally validated using an industrial case study. The computational experiment results indicated that the proposed GA with new crossovers are able to find the optimal solution for ALB-RC better than popular combinatorial crossovers. Meanwhile, the results of industrial case study validated that the proposed ALB-RC model is capable to be used for the real industrial problem. At the same time, the result indicated that the GA with rank-based crossover is capable to optimise real-life problem. As a comparison, the number of workstation, machine/tools and workers had reduced between 10 – 15% for the optimised layout using GA with RBC, compared with the original layout in the case study problem.

ABSTRAK

Pengimbangan rangkaian pemasangan (ALB) adalah berkaitan dengan pembahagian tugas pemasangan ke stesen kerja untuk mendapatkan beban kerja yang hampir sama di setiap stesen. Kajian-kajian terdahulu mengandaikan setiap stesen kerja mempunyai keupayaan yang sama dari segi mesin, peralatan dan kemahiran pekerja. Sejak akhir-akhir ini, penyelidik mula mempertimbangkan kekangan sumber dalam mengimbangi rangkaian pemasangan seperti mesin dan pekerja. Pengoptimuman ALB dengan kekangan sumber memberi manfaat besar kepada industri seperti meningkatkan kecekapan pemasangan, memanfaatkan sumber sepenuhnya dan dapat mengurangkan kos pengeluaran. Penyelidikan ini membentangkan masalah pengimbangan rangkaian pemasangan dengan kekangan sumber (ALB-RC) dengan objektif untuk meminimumkan stesen kerja, mesin dan bilangan pekerja. Untuk tujuan pengoptimuman, penyelidikan ini memperkenalkan algoritma genetik (GA) dengan dua silangan baru. Silangan ini dibangunkan dengan menggunakan pendekatan kedudukan dan dikenali sebagai jenis silangan berasaskan kedudukan jenis I dan jenis II (RBC-I dan RBC-II). GA dengan silangan baru diuji terhadap silangan-silangan gabungan sedia ada yang popular. Ia diuji ke atas 17 masalah piawai ALB. Prestasi GA yang dicadangkan dengan silangan baru pada pengoptimuman ALB-RC akhirnya disahkan menggunakan kajian kes industri. Hasil eksperimen pengkomputeran menunjukkan bahawa GA yang dicadangkan dengan silangan baru dapat mencari penyelesaian optimum yang lebih baik untuk ALB-RC berbanding silangan yang sedia ada. Sementara itu, keputusan daripada kajian kes di industri mengesahkan model ALB-RC yang dicadangkan boleh digunakan di lapangan industri yang sebenar. Pada masa yang sama, keputusan kajian kes juga menunjukkan GA dengan silangan yang baharu mampu mengoptimumkan masalah sebenar di industri dengan lebih baik. Sebagai perbandingan, bilangan stesen kerja, mesin dan pekerja telah dapat dikurangkan di antara 10 – 15 % melalui susunatur yang dioptimakan menggunakan GA dengan silangan baharu berbanding dengan susun atur asal di industri.

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LIST OF SYMBOLS

A_s	Workstation availability index
ct	Cycle time
ct_{max}	Maximum cycle time
$\bar{f}$	Normalised objective function
F(x)	Combined fitness function
$f_i(x)$	i^{th} objective function
n	Number of assembly task
nws	Number of workstation
pt_i	Processing time in workstation *i*
t_i	Assembly time for task *i*
w_i	Constant weight for $f_i(x)$
y_{ms}	Machine availability index
z_{ws}	Worker availability index

LIST OF ABBREVIATIONS

ACO	Ant Colony Optimisation
ALB	Assembly line balancing
ALB-RC	Assembly line balancing with resource constraints
CX	Cycle Crossover
DP	Dynamic programming
GA	Genetic Algorithm
GALBP	Generalised Assembly Line Balancing Problem
LE	Line efficiency
LP	Linear programming
MMAL	Mixed Model Assembly Line
MOGA	Multi-objective genetic algorithm
MuMAL	Multi Model Assembly Line
NLP	Non-linear programming
NP-hard	Non-deterministic polynomial-time hard
OX	Ordered Crossover
PM	Precedence matrix
PMX	Partially Matched Crossover
PSO	Particle Swarm Optimisation
RBC-I	Rank based crossover type I
RBC-II	Rank based crossover type II
SALBP	Simple Assembly Line Balancing Problem
SALBP-1	Simple Assembly Line Balancing Problem Type 1
SALBP-2	Simple Assembly Line Balancing Problem Type 2
SALBP-E	Simple Assembly Line Balancing Problem Type E
SI	Smoothness index
TSAL	Two sided Assembly Line
USAL	U-Shaped Assembly Line

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